Terrestrial Planet Finder Mission

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TPF Coronagraph System Design Studies

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Design Team Process

- Design Team started work on Minimum Mission
  - Starting Point
    - Ball Aerospace design
    - Formed a new design team
      - JPL, GSFC, Ball Aerospace, Lockheed Martin, Northrop Grumman
- Process
  - Make design trades to arrive at an acceptable TPF Coronagraph
  - Analyze
  - Document performance

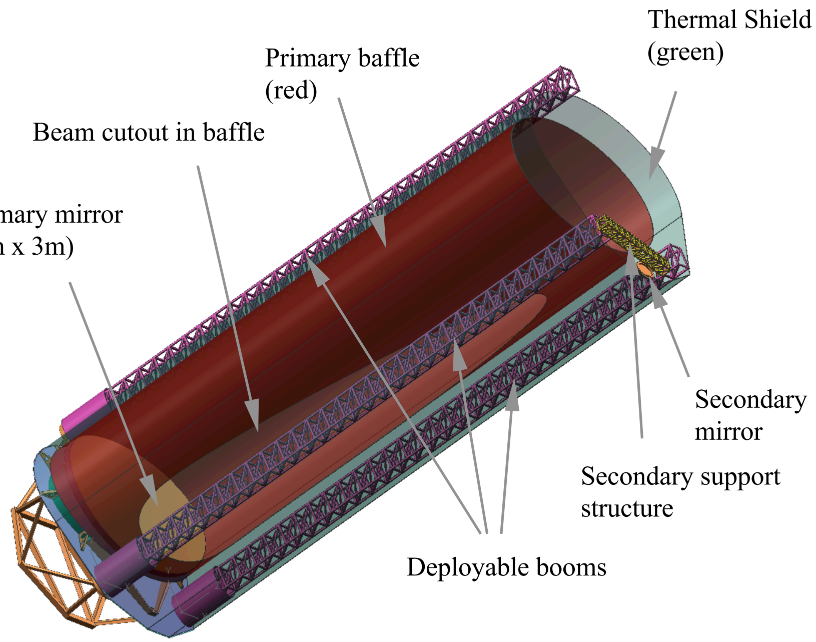
- Constraints
  - Minimum Mission design only in FY'03
    - –Deferred the start of work on Full Mission to late October '03
  - Existing launch vehicles with NASA contract
    - –Delta IV Heavy
  - Conventional power system
  - Monolithic Primary Mirror

Design Options

- Optical
  - Larger telescope at 4 λ/D or smaller telescope at 3 λ/D
  - Cassegrain or Gregorian
  - Primary Mirror to Secondary Mirror distance
- Thermal
  - Sunshade: cocoon shaped v-groove or flat v-groove
  - Primary Mirror material: ULE or SiC
- Mechanical Configuration
  - Spacecraft location: behind or on side of Primary Mirror
  - Orientation in booster fairing: vertical or tilted
  - Launch support structure: interface plate, tilted support structure or support cylinder
- Orbit selection
  - L2 or Earth drift away

Mechanical Configuration Trades

Time Frame: March-April 2003
Concept: Boom deployment of secondary



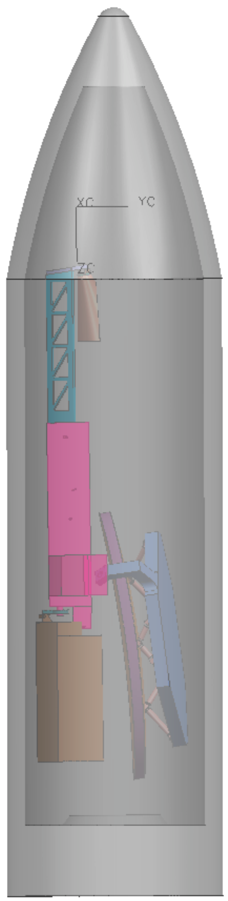
Pros:
1) Secondary, thermal shield, and baffle deployed in single deployment
2) Simple

Cons:
1) Poor secondary support and stability
2) Poor boom support for stiffness
3) Deployment accuracy

Mechanical Configuration Trades

Time Frame: May 2003

Concept: Single compound axis rotation with instrument and spacecraft along secondary axis



Pros:

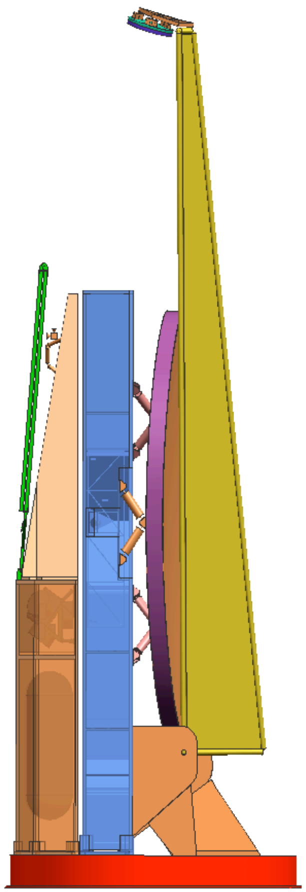
1) Single actuation
2) Stiff secondary support
3) Efficient use of stiff secondary tower structure as instrument package

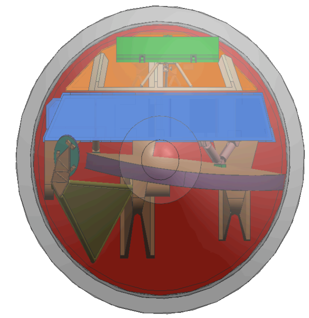
Cons:

1) Poor primary to secondary placement in stowed position
2) Limits length of telescope
3) Difficult to carry load to booster interface – could require two interfaces to S/C and primary
4) Compound and off primary center axis of rotation

Mechanical Configuration Trades

Time Frame: June 2003
Concept: Straight Single Axis deployment





Pros:

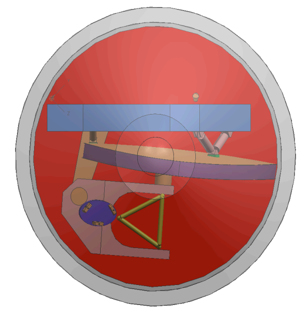
1) Simple motion
2) Single actuation to deploy secondary
3) Conducive to a favorable booster interface and load path

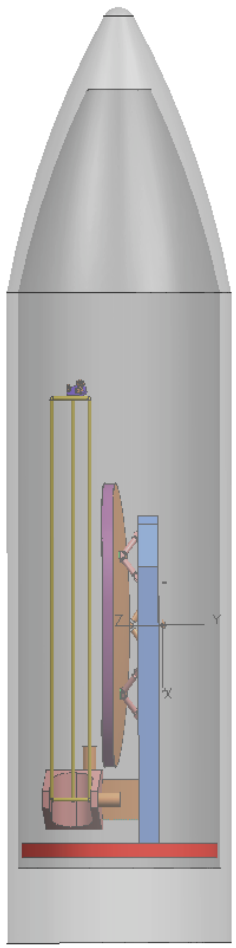
Cons:

1) Offset CG in flight and stowed configurations
2) High CG placement in shroud in stowed configuration
3) Limits length of telescope without having to add another hinge
4) Skewed tower to clear light beam
5) Increases size of v-groove shield and difficult deployment
6) Requires large base footprint attachment to booster to control frequency
7) Longer tower (due to lean) and limited tower base size
8) Limits S/C and primary support thickness
9) Not optimal placement of tower in shroud

Mechanical Configuration Trades

Time Frame: June 2003
Concept: Straight Two Axes deployment



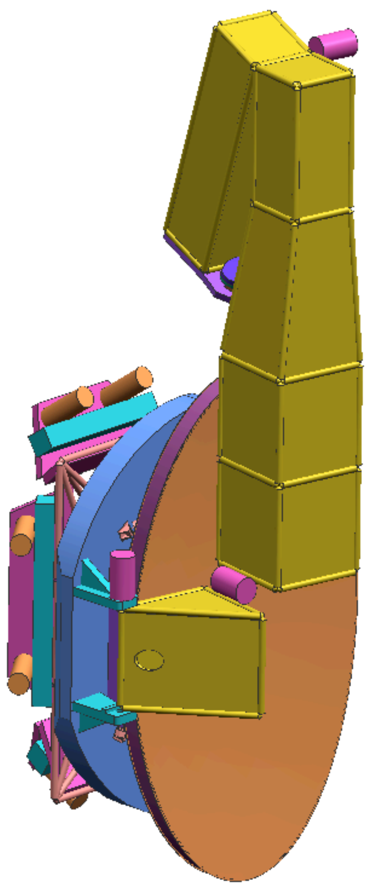


Pros:
1) Favorable secondary to primary alignment
2) Simple motion – rotation axes are perpendicular to each other
3) Allows growth of telescope length
4) Better CG location in stowed configuration
5) Equal sided member secondary tower

Cons:
1) Offset CG in flight configuration
2) High CG placement of primary in shroud in stowed configuration
3) Increases size of v-groove shield
4) Longer tower (due to lean) and severe limitation of tower base size
5) Limits S/C and primary support thickness
6) Not conducive to a favorable booster interface and load path, but still requires large base footprint attachment to control frequency
7) Two actuators to deploy secondary tower

Mechanical Configuration Trades

Time Frame: July 2003
Concept: Symmetric system, 3 axis secondary deployment



Pros:
1) Favorable secondary to primary alignment
2) Simple motion – rotation axes are perpendicular to each other
3) Allows growth of telescope length
4) Better CG location in stowed and flight configuration
5) Accommodates v-groove deployment system

Cons:
1) Limits secondary tower base size
2) Not conducive to a favorable booster interface and load path (mitigation – created cylindri to support loads during launch)
3) Three actuators to deploy secondary

Current Mechanical Configuration

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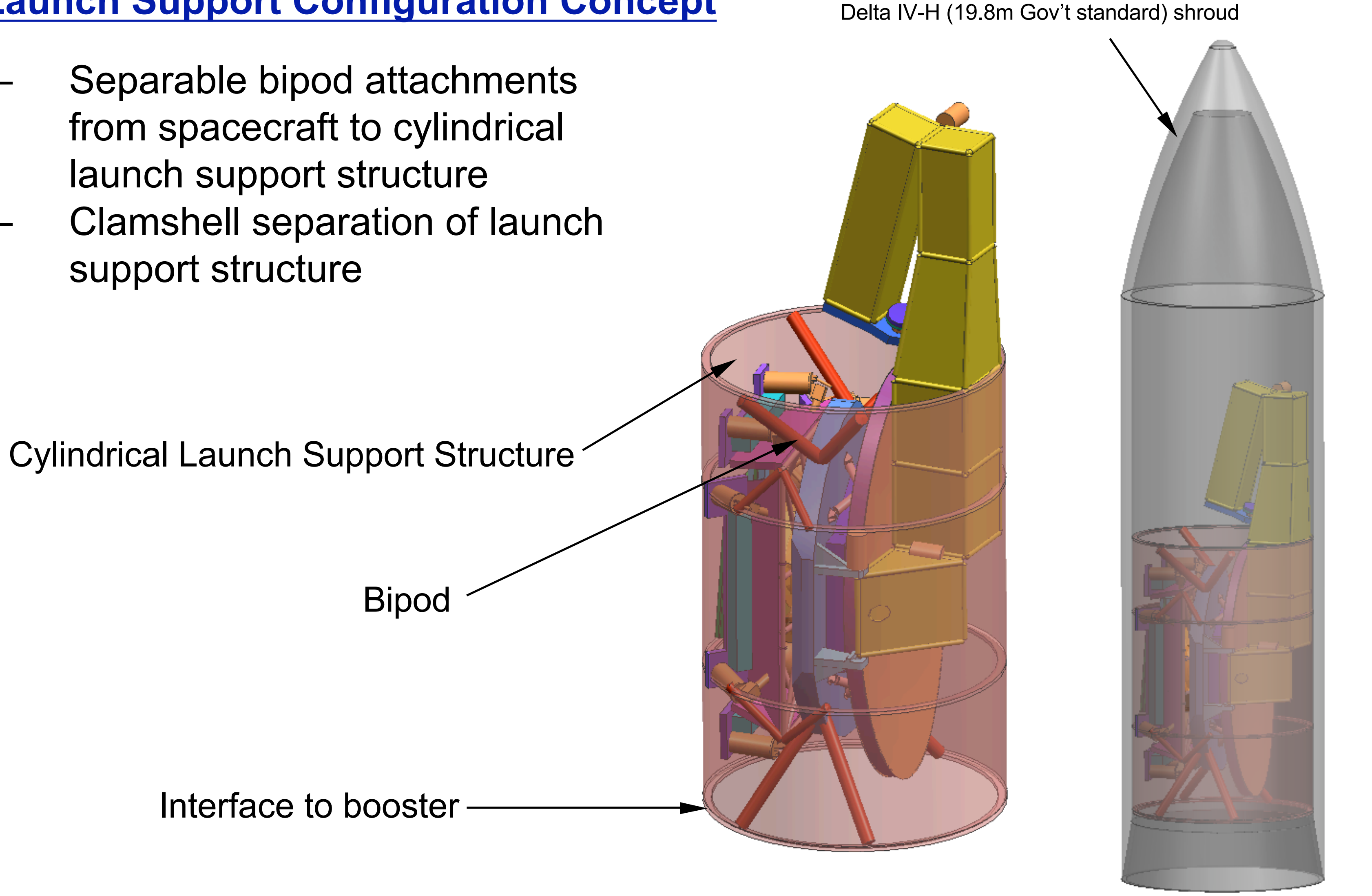
Launch Support Configuration Concept

– Separable bipod attachments from spacecraft to cylindrical launch support structure
– Clamshell separation of launch support structure



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Current Conceptual Thermal Design

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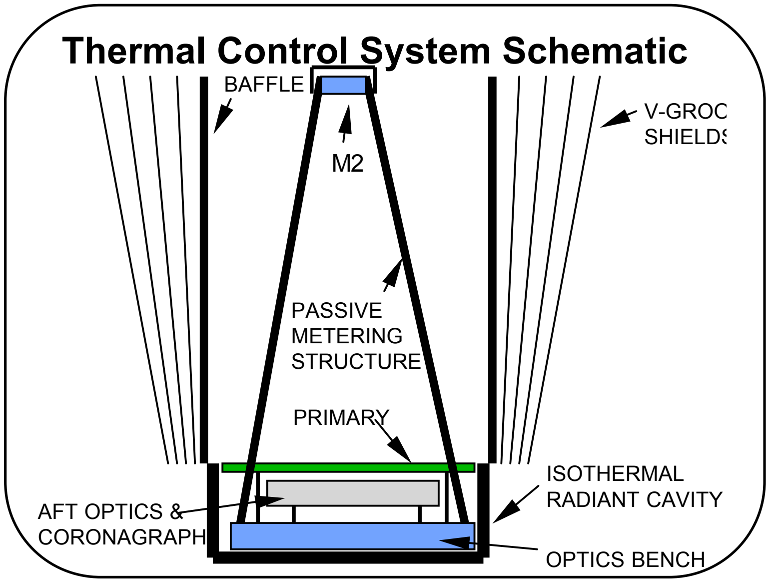
- Cocoon (octagonal) shaped v-groove sunshield consisting of 6 layers including inner baffle. Layers will be ~1 mil Kapton coated with vacuum deposited aluminum (VDA), spaced ~50 mm near the base of the telescope and angling away from each other by ~3 degrees.
- Sunshield will be deployed from stowed configuration by extendable masts.
- Inner baffle layer will be optically black on the inner surface for stray light control.

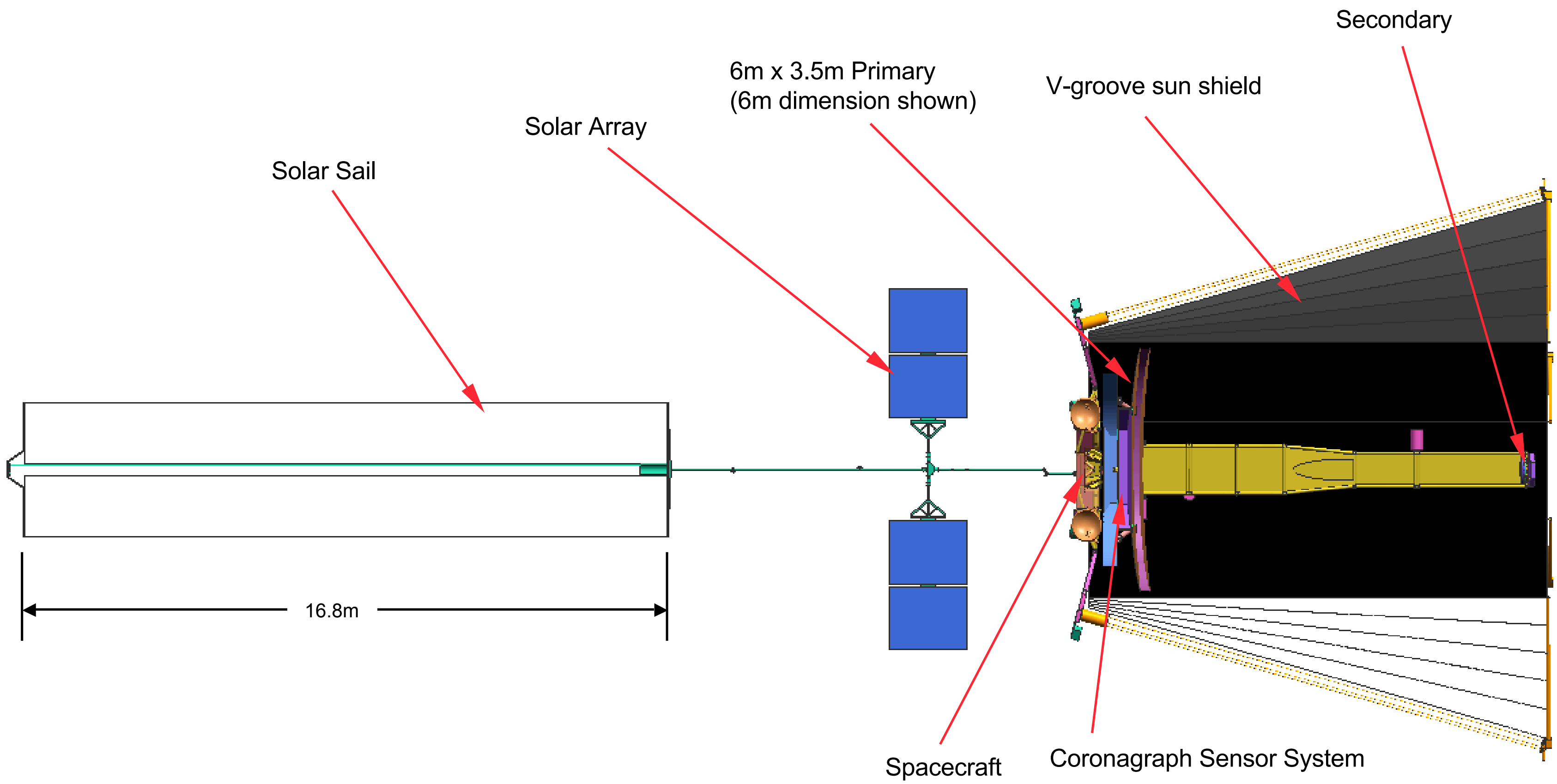


- Active thermal control to maintain primary mirror and all other optics near room temperature.
  - –Radiative cavity, possibly using zoned heater control and phase-change material to maintain primary mirror.
- Passive thermal control of secondary support structure to maintain equilibrium temperatures.

Current Mechanical Configuration

Configuration Concept Overview

- 10m primary to secondary optical prescription



Current Mechanical Configuration

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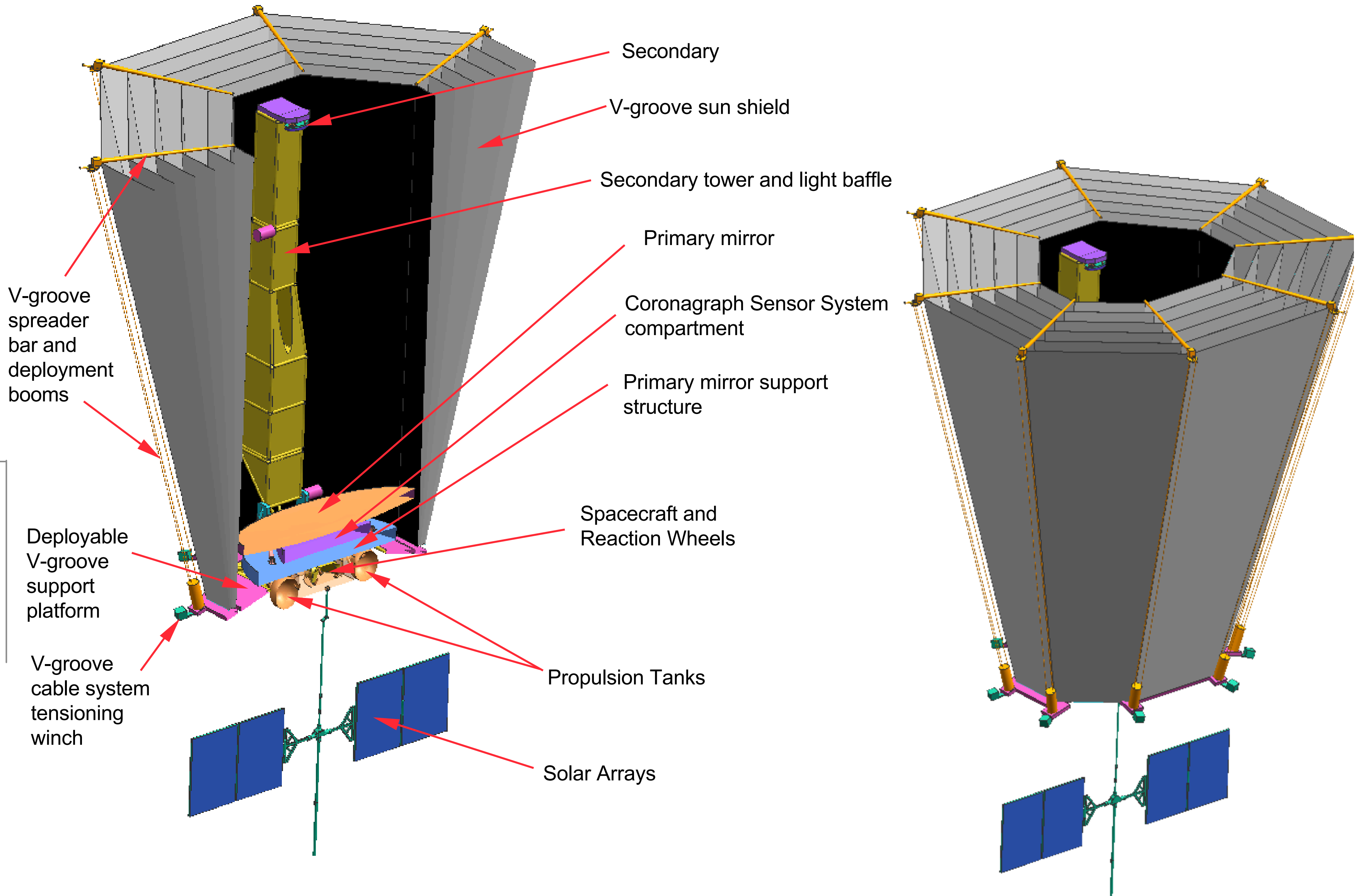

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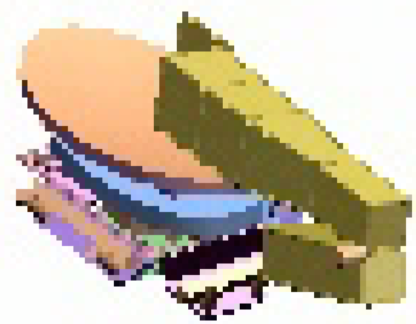

Thermal Modeling

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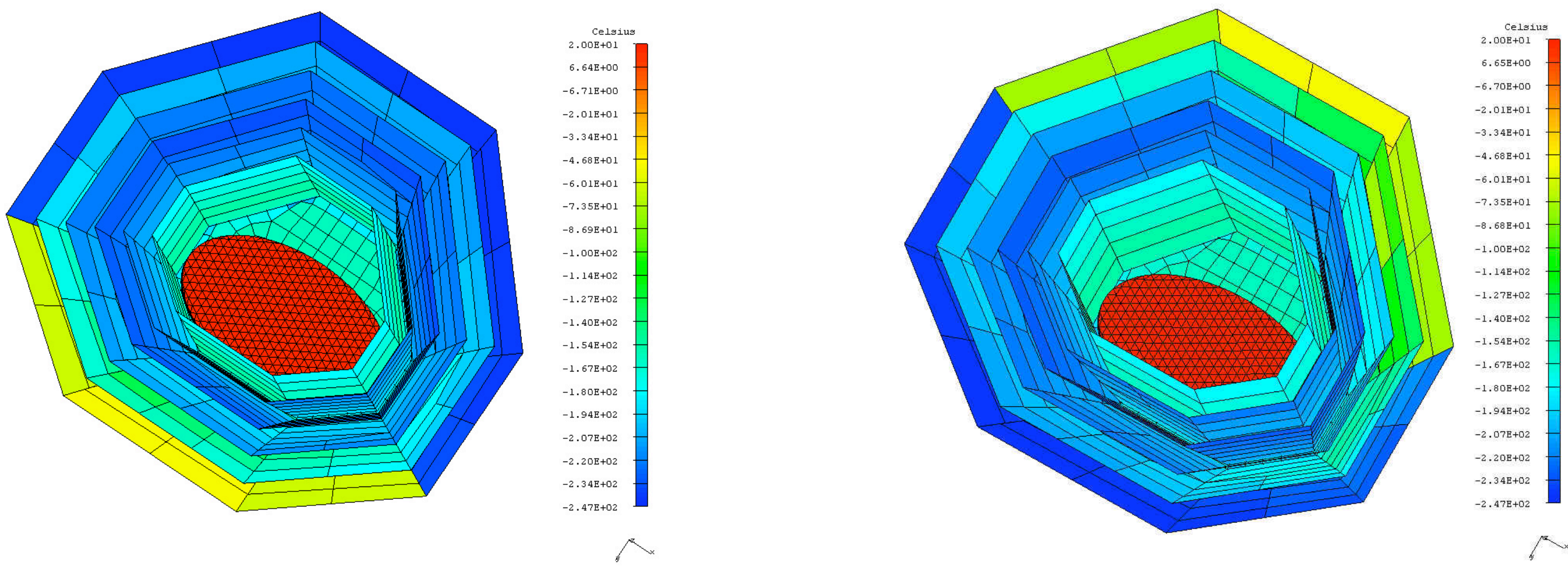

Steady State Thermal Analysis of Sunshield and Primary Mirror

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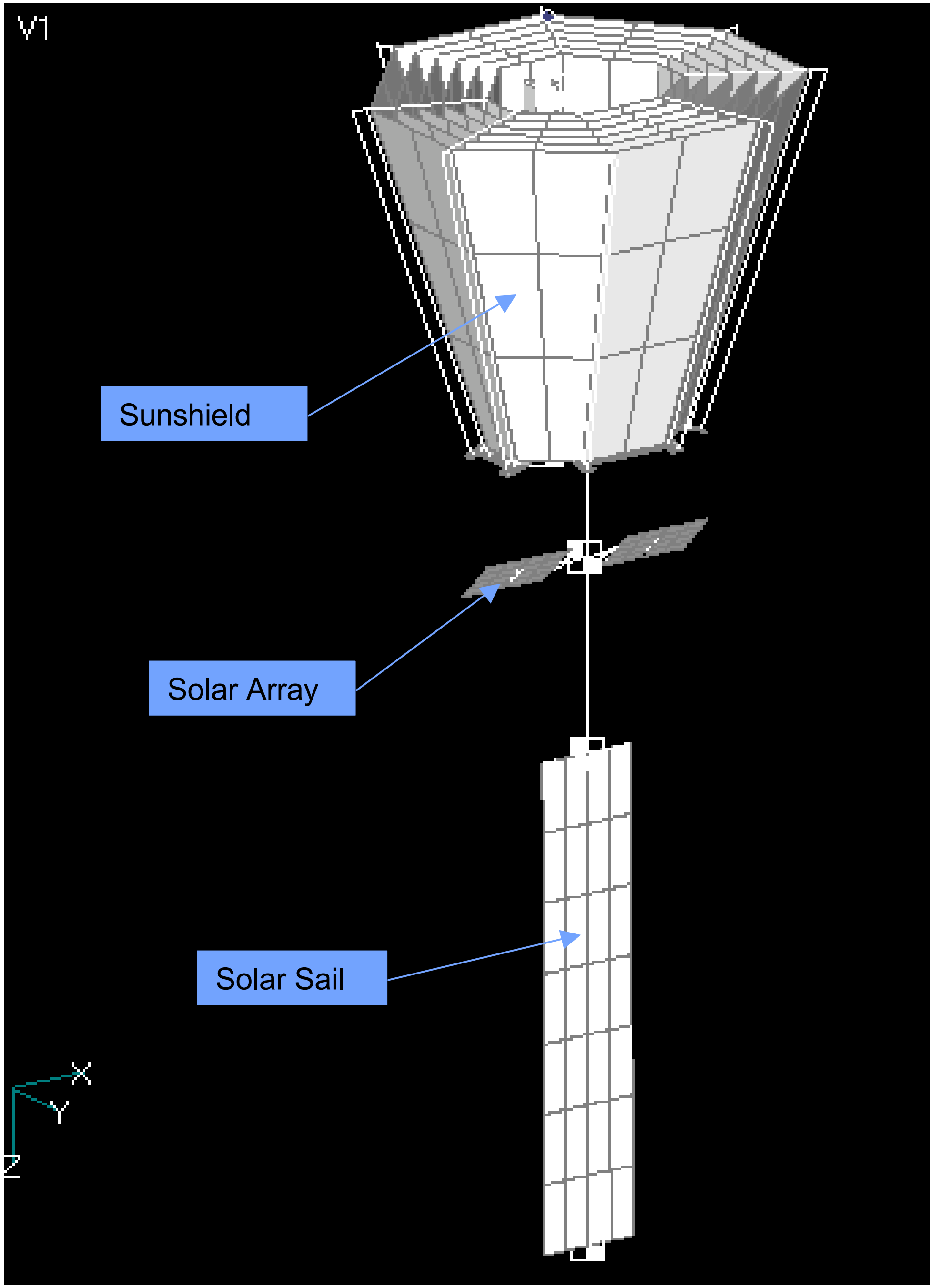
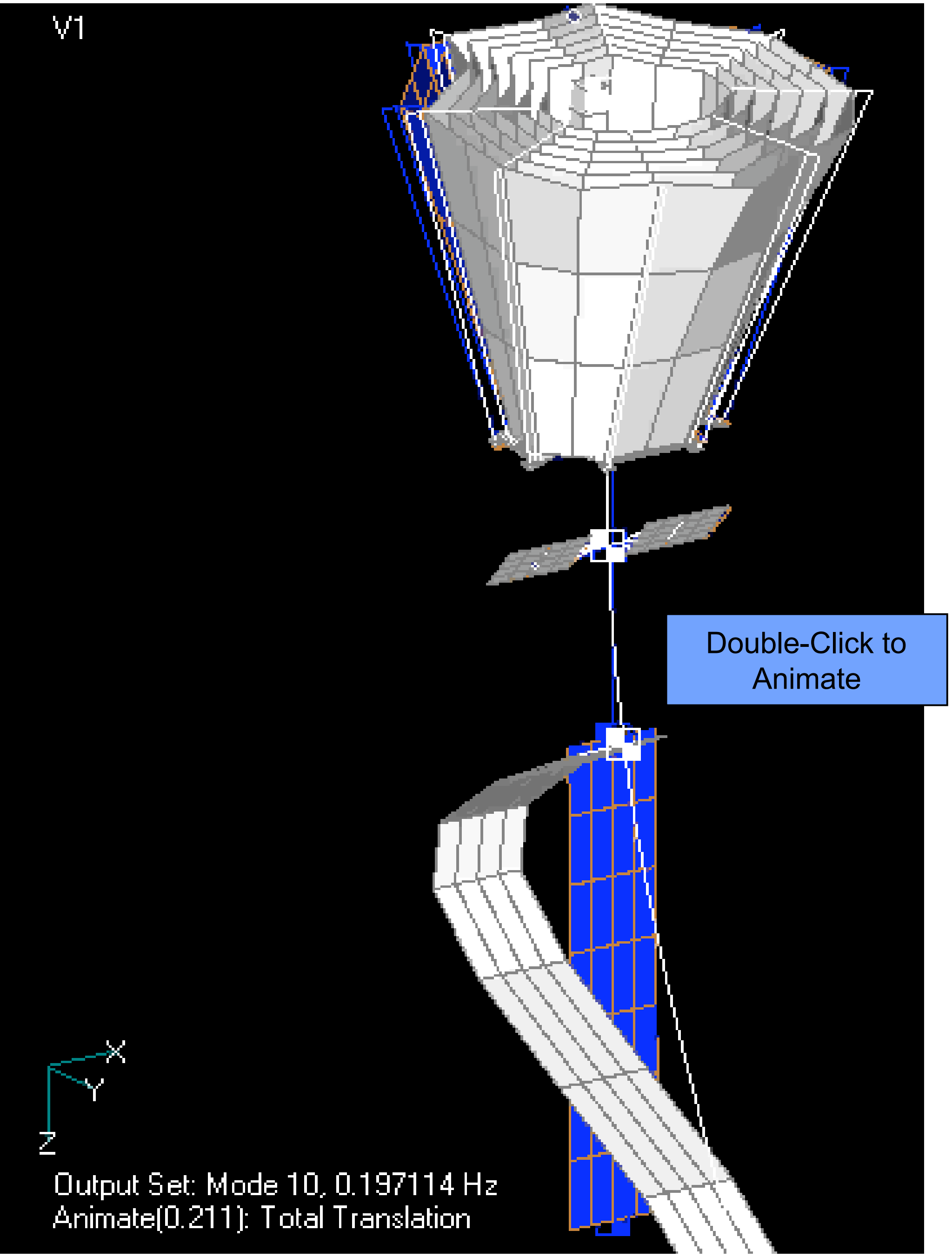
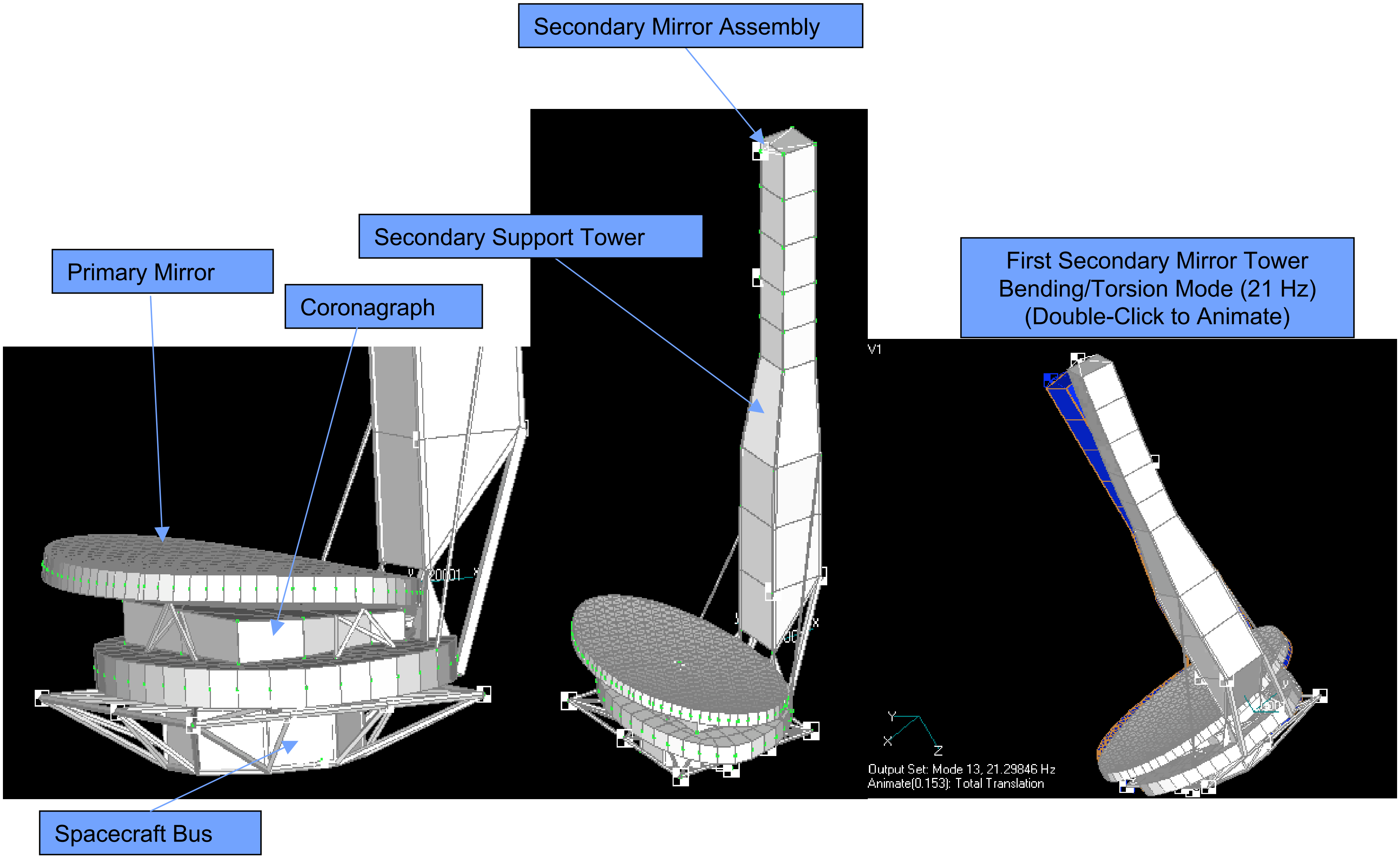


Structural Finite Element Model Plot



Magnified Displacements for Vib Mode 10 (.2 Hz)



Model Plots of Primary & Secondary Sub-Assemblies

Orbit Selection Summary

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- Preliminary orbit selection made in June, 2003
  - Evaluated earth orbits, deep space trajectories, L2 orbits & Earth Drift-Away orbits, with emphasis on the latter 2 options
- Primary criterion in selecting between L2 and Earth Drift-Away orbits are: propulsion, telecommunications and viewing constraints
- Selected L2 as preliminary choice primarily based upon viewing constraints
  - Assumed cannot point telescope within 90° of earth and moon, regardless of rang
- Current studies consider reduced earth/moon flux with range and may indicat a preference for Earth Drift-Away orbits
  - At some time after launch the brightness of earth and moon are no brighter than Venus, for example, which the instrument must practically accommodate

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Trade Matrix as of June '03

Parameter	units	Large L2	Small L2	Drift-Away
Time to Operating Orbit	days	100	100	1
Propellant Mass (Includes 60kg Momentum Mgt)	kg	400	**817**	60
Current Usable Dry Mass (40% margin)	kg	5251	4834	5487
Propellant Tank Diameter (single spherical)	cm	110	**140**	50
Transmitter Power	W	20	20	80
Antenna Size (Diameter or Side Length)	cm	13	13	**202**
Antenna Pointing Accuracy (for 1dB loss)	deg	5	5	0.35
Earth/Moon Viewing Restriction (1 side of anti-sun hemisphere)	deg	**20-40**	3-18	**75-90**

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Earth and Moon Restriction Angles for L2 Halo Orbit

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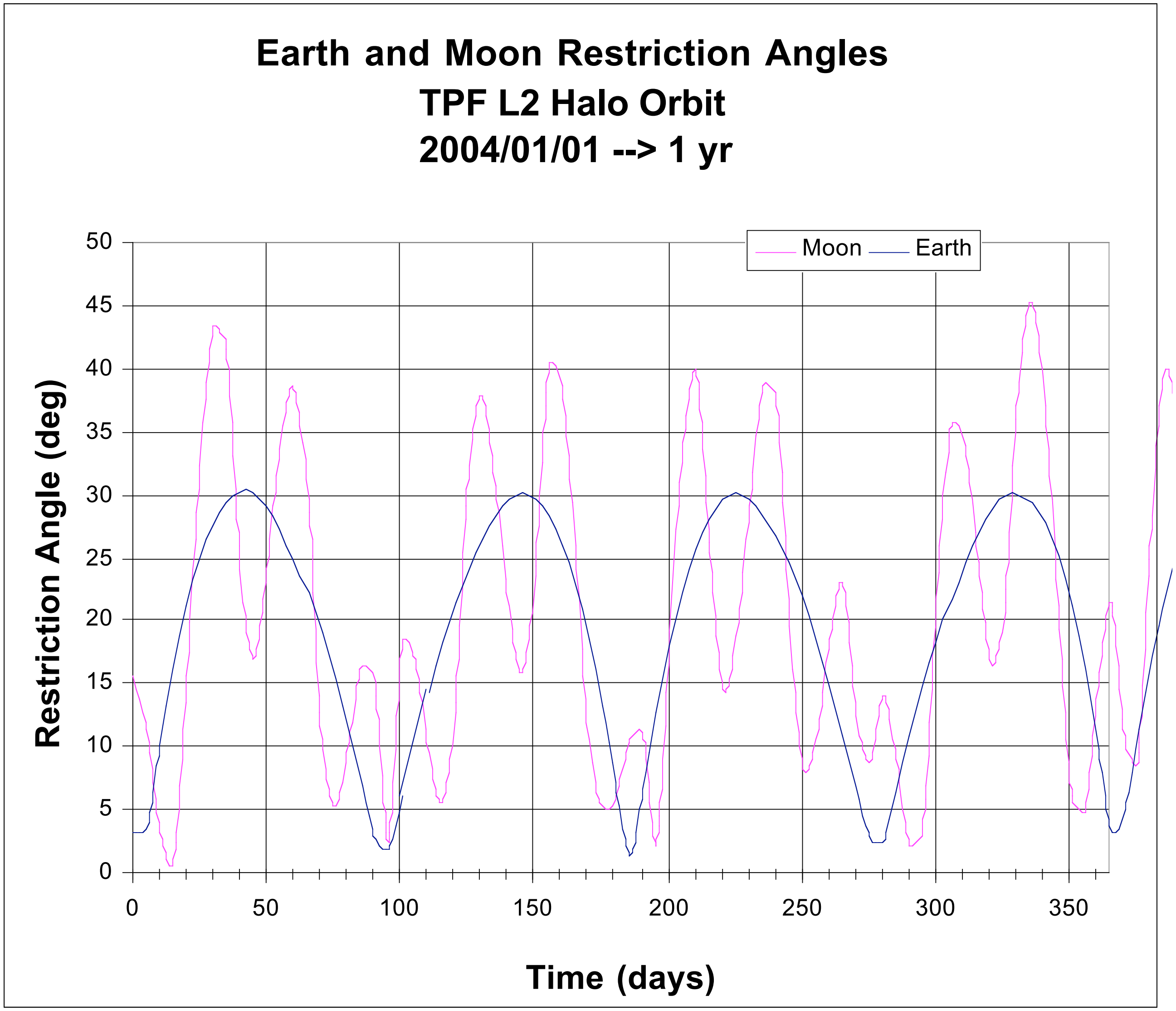

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Solar Avoidance
Limits Observation to 6 Month Sampling

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- 180 degree solar avoidance angle
  - 6-month season to see any star
- Best case planet orbit is face on
  - planet always appears at the orbital radius (assuming circular orbit)
- Worst case planet orbit is inclined 90 degrees
  - see it edge-on
  - planet-star separation is a sine wave
- Impact of sampling scenario due to seasonal observations
  - Maximum observed separation of planet and star is a function of period and phase of the orbit

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Sampling Due to Solar Avoidance

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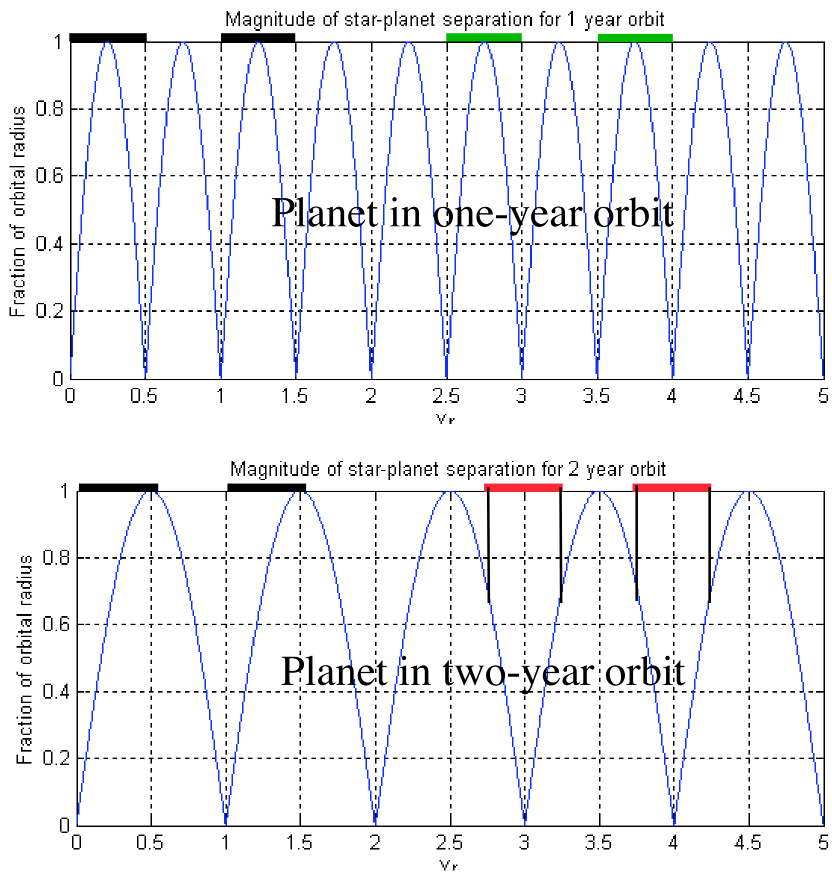
Bold lines indicate periods of star observation.

Two different starting phases are shown (different colors).

For orbits up to 1.5 years, the peak separation is sampled no matter what phase is chosen.

Red lines show the worst-case phase for the two-year orbit, where the maximum star-planet separation observed is 0.71 of the orbital radius.



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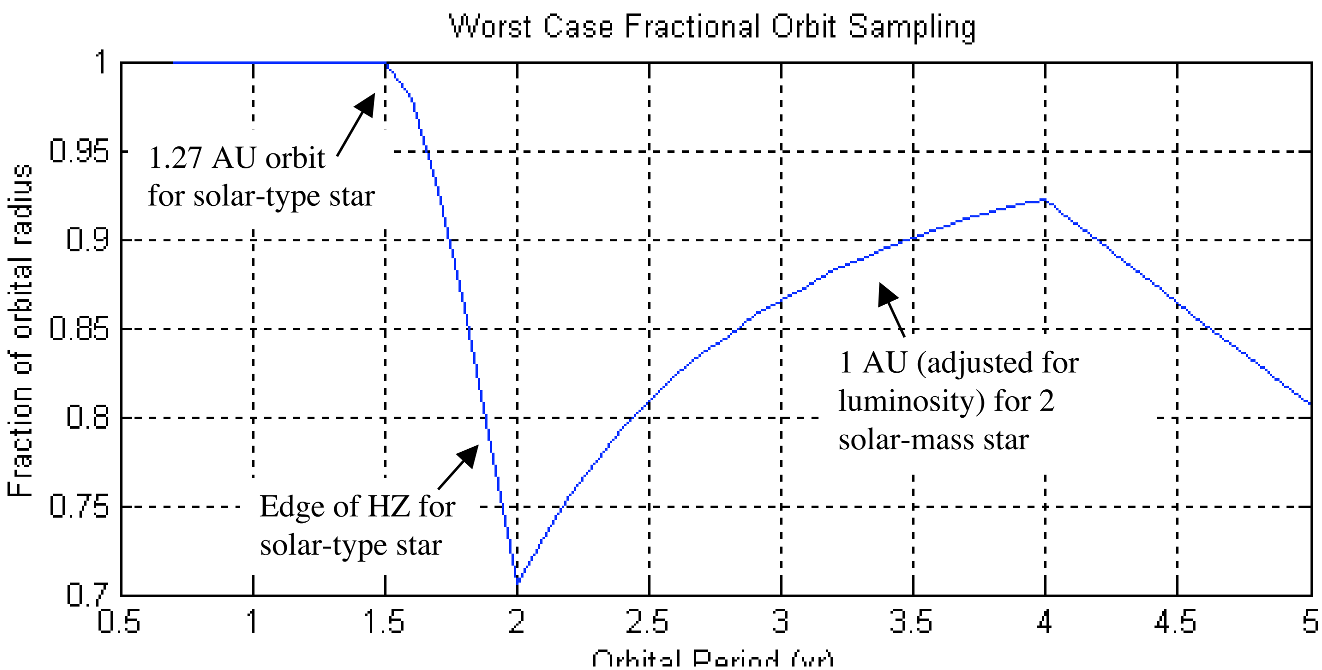
Worst Case vs. Orbital Period for 6 Month On, 6 Month Off Sampling



For orbits up to 1.5 yr, the 6-month on, 6-month off, 6-month on sampling has no penalty. The worst case is a 2-year period. The 2-yr case is not helped by extending the length of the mission. Other cases are helped by extending the length of the mission because a larger fraction of phase-space is sampled.

Note: Period for a 2-solar mass star, equivalent 1 AU orbit (1 AU is adjusted to 2.8 AU), is 3.36 yr. 1.5 AU orbit (adjusted for luminosity) has period of 6.2 yr.

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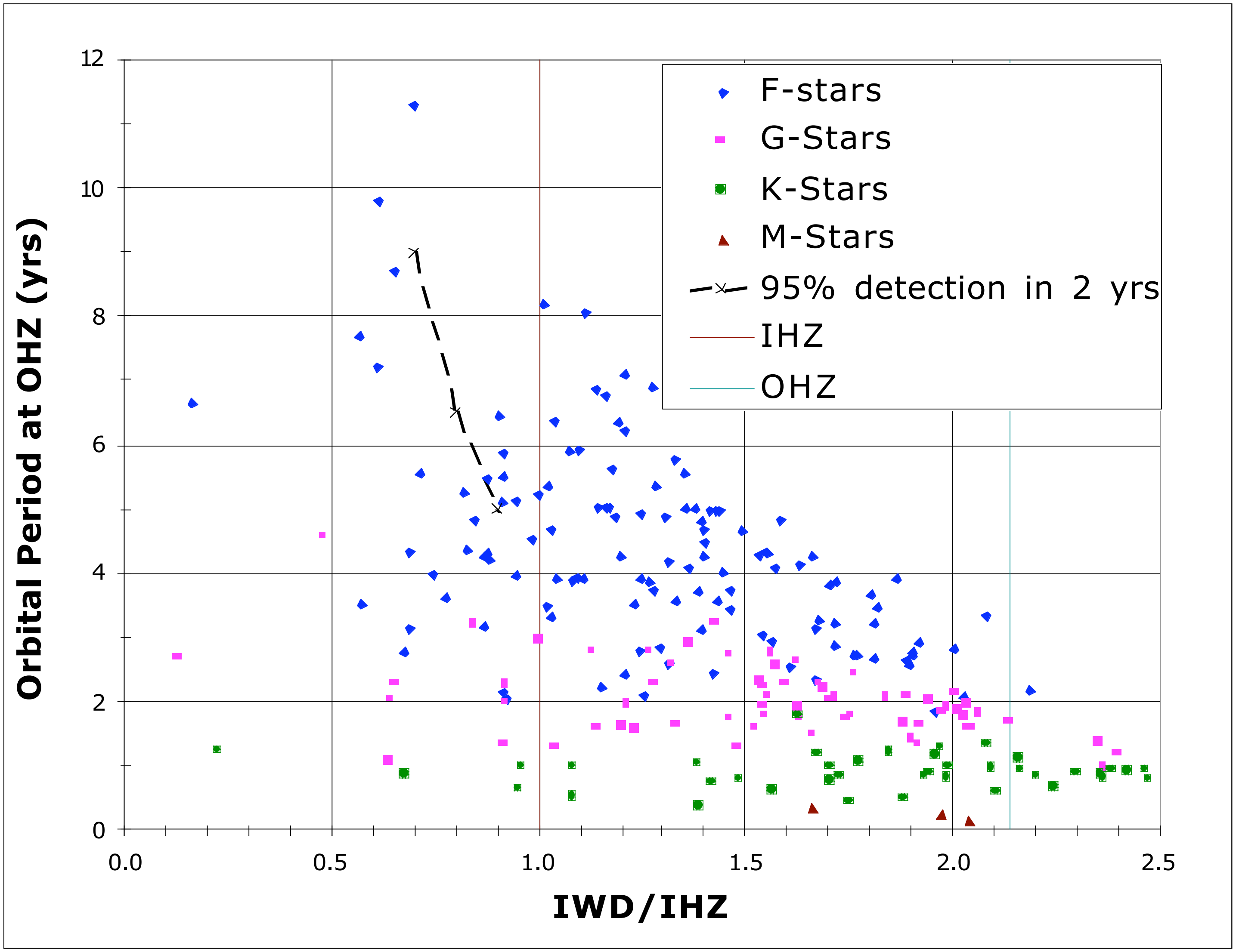

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Summary of FY'04 Study Plan

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- Minimum Mission
  - Thorough optical, thermal and structural analysis
  - Mechanism definition
  - Spacecraft design

- Full Mission Design
  - Design trades
  - Thorough optical, thermal and structural analysis
  - Mechanism definition
  - Spacecraft design

- Increased participation from
  - Ball
  - GSFC
  - LM
  - NGST

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